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EVALUATION OF SURFACE SHEAR STRENGTH MEASUREMENTS FOR USE IN LABORATORY MOBILITY STUDIES

by

T. R. Patin

May 1972

Sponsored by U. S. Army Materiel Command

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Conducted by U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi

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13. ABSTRACT

Laboratory tests were conducted to determine which method of obtaining five different soil-to-rubber shear measurements with two rotary-shear devices, a Cohron sheargraph and a spline shear device, would produce the most consistent measurements or quantitative indexes of surface soil strength. The tests were made at 34.5-, 68.9-, and 103.4-kN/m^2 normal pressures on a fat clay whose surface moisture content ranged from 26.5 to 45.9 percent. It was found that peak shear measurements for the full range of soil strengths used could be obtained only at the normal pressure of 34.5 kN/m^2 because of excessive sinkage of the shear head at the higher normal pressures in the softer soils. The peak shear measurements with the Cohron sheargraph, with an in-air calibration, at a normal pressure of 34.5 kN/m^2 were the most consistent and are recommended for further study to determine their validity in surface condition-vehicle performance research.

Details of illustrations in this document may be better studied on microfiche

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Foreword

The study reported herein was conducted in furtherance of DA Project 1T062103A046, "Trafficability and Mobility Research," Task 03, "Mobility Fundamentals and Model Studies," under the sponsorship and guidance of the Research, Development and Engineering Directorate, U. S. Army Materiel Command.

The tests were conducted in 1970 by personnel of the Mobility Research Branch, Mobility and Environmental Division, U. S. Army Engineer Waterways Experiment Station (WES), under the general supervision of Messrs. W. G. Shockley and S. J. Knight and Dr. K.-J. Melzer and the direct supervision of Mr. T. R. Patin, who also prepared this report.

COL Levi A. Brown and COL Ernest D. Peixotto were Directors of the WES during this study and preparation of this report. Mr. F. R. Brown was Technical Director.

Contents

Conversion Factors, Metric to British Units of Measurement

Metric units of measurement used in this report can be converted to British units as follows:

Multiply	By	To Obtain
centimeters	0.3937	inches
square centimeters	0.1550	square inches
kilonewtons per square meter	0.1450	pounds per square inch

Summary

Laboratory tests were conducted to determine which method of obtaining five different soil-to-rubber shear measurements with two rotary-shear devices, a Cohron sheargraph and a spline shear device, would produce the most consistent measurements or quantitative indexes of surface soil strength. The tests were made at 34.5-, 68.9-, and 103.4-kN/m^2 normal pressures on a fat clay whose surface moisture content ranged from 26.5 to 45.9 percent.

It was found that peak shear measurements for the full range of soil strengths used could be obtained only at the normal pressure of 34.5 kN/m^2 because of excessive sinkage of the shear head at the higher normal pressures in the softer soils. The peak shear measurements with the Cohron sheargraph, with an in-air calibration, at a normal pressure of 34.5 kN/m^2 were the most consistent and are recommended for further study to determine their validity in surface condition-vehicle performance research.

EVALUATION OF SURFACE SHEAR STRENGTH MEASUREMENTS FOR USE IN LABORATORY MOBILITY STUDIES

Background

1. Surface soil conditions have long been known to influence the mobility of ground vehicles, and tests have been conducted at the U. S. Army Engineer Waterways Experiment Station (WES) to study the effects of wet surface conditions on the performance of standard-size pneumatic tires.[1,2] Although these studies did provide some answers to the problem, they did not result in a satisfactory method for predicting the effects of surface condition on the performance of tires, i.e. surface condition was not described in commensurate terms. Two devices were used, a Cohron sheargraph and a cone penetrometer. The sheargraph, a rotary shear-type device, yielded measurements that were somewhat more indicative of the tire performance than those obtained with the cone penetrometer, a probe-type device. However, the relation between sheargraph readings and the tire performance was not as clear-cut as was desired. One reason for the vagueness of the relation appeared to be the erraticism or inconsistency of the sheargraph itself, caused at least partially by human error that could not be avoided in the hand-operated technique used.

2. Additional studies to develop satisfactory surface condition-tire performance relations are planned for the future. Meanwhile, it was felt advantageous to devote a small effort to the development or selection of a consistent test with a rotary-shear device. A consistent test is not necessarily a valid test, but no test can be valid unless it is first consistent. This limited study was therefore undertaken to determine which of several readily available device-technique combinations appeared to be the most consistent. The most consistent combination, along with any other device-test technique combination that may subsequently be found to be equally attractive, would be used in future

studies to develop means of predicting the effects of surface condition on tire performance.

Purpose

3. The purpose of this study was to determine the most consistent of five different methods (specific instrument-test techniques) for obtaining shear strength measurements with two available instruments under controlled laboratory conditions.

Scope

4. This study was limited to two devices, five methods of operation (three for one device, two for the other), three normal loads, and one soil prepared to various strengths.

5. The Cohron sheargraph[3] and a spline shear device were used in carefully controlled laboratory tests to measure the soil-to-rubber shear under normal pressures of 34.5, 68.9, and 103.4 kN/m^2.* These values (equivalent to 5, 10, and 15 psi, respectively) were selected simply because they are the normal pressures commonly used in determining cohesion and angle of internal friction of soil with the Cohron sheargraph. All measurements were taken with the 12.9-sq-cm rubber shear head that is supplied with the sheargraph. Tests were conducted in molds specially built for the study and in soil bin facilities normally used for tire testing.** The soil was a fat clay with bulk moisture contents ranging from 28 to 43 percent, and surface moisture contents from 26.5 to 45.9 percent. The surface moisture contents were measured immediately after the shear measurements at a depth of 0.5 cm.†

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* A table of factors for converting metric to British units of measurement is given on page ix.

** Descriptions of the techniques used for building the molds and the soil bins are given in references 4 and 5.

† This was necessary because the surface moisture content changed with time and was slightly different from the bulk moisture content of a whole mold.

Soil penetration resistance values ranged from approximately 100 to 700 kN/m^2.

Test Soil

6. The soil used in the study was a fat clay classified CH according to the Unified Soil Classification System. Its liquid limit (LL) and plasticity index (PI) were 65 and 41, respectively. The consistencies tested ranged from very soft to stiff (fig. 1). All test specimen were built to at least 90 percent saturation.

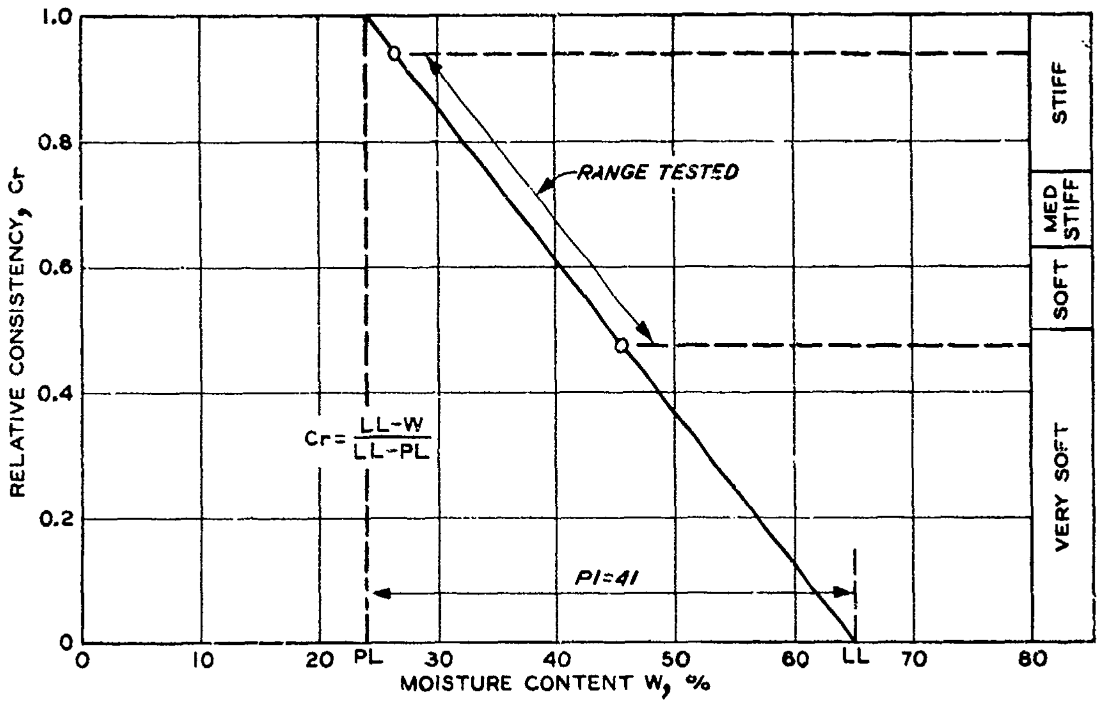

Fig. 1. Moisture content versus relative consistency relations for test soil

Equipment and Test Procedures

Cohron sheargraph[3]

7. The Cohron sheargraph is a portable, manually operated field instrument that is capable of producing rapid soil strength measurements; however, its accuracy depends largely on the skill of the operator. For

carefully controlled measurements in this program, the sheargraph was mounted in a machine so that pressure and torque could be applied mechanically. The mechanical operation and the addition of a torque cell between the shear head and the spring (fig. 2) were the only modifications made to the field instrument. It was felt that the torque cell, connected to an x-y recorder, would yield more accurate values of surface shear than those recorded on the barrel chart.

8. To obtain shear measurements, the vertical load was applied by screwing down the loading platform until the desired normal pressure was reached. This normal pressure is indicated on the barrel chart (fig. 2). Torque was then applied until a peak maximum shear value was reached (also indicated on the chart).

9. Of the five different measurements of shear at a given normal pressure that were studied, three were obtained with the Cohron sheargraph by the following methods:

- a. Method A. The standard value of shear strength (S_A) was obtained from the barrel chart.
- b. Method B. A peak value of shear strength (S_B) was obtained from the x-y recorder plot; shear was measured from a datum established while the shear head was still in air (in-air zero).
- c. Method C. Method C was the same as Method B, except the shear datum was set at zero after the head was on the soil surface and loaded, but before torque was applied (loaded zero, S_C).

Representative results are shown in fig. 3.

Spline shear device

10. The spline shear device (fig. 4) was built at the WES in 1966 and was used at that time for surface traction studies. It consists of a 12.9-sq-cm rubber shear head (from a Cohron sheargraph) mounted on a ball bushing with free vertical movement. Normal pressure is applied by deadweight loading on the ball bushing, instead of spring loading as with the Cohron sheargraph. Torque is applied to the spline shaft and, in turn, to the shear head; it is recorded, along with the angle of

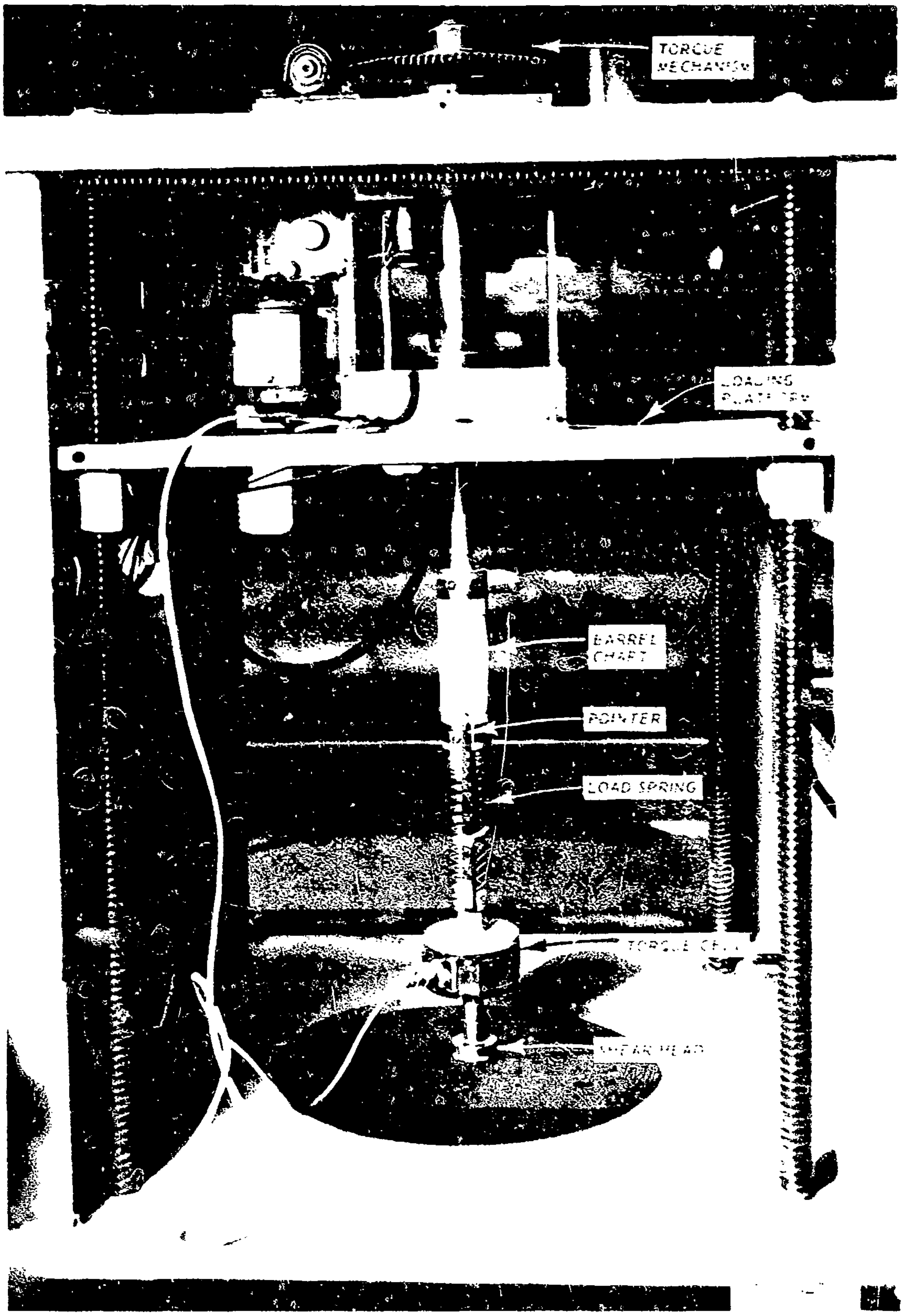

Fig. 2. Mechanical Cohron sheargraph

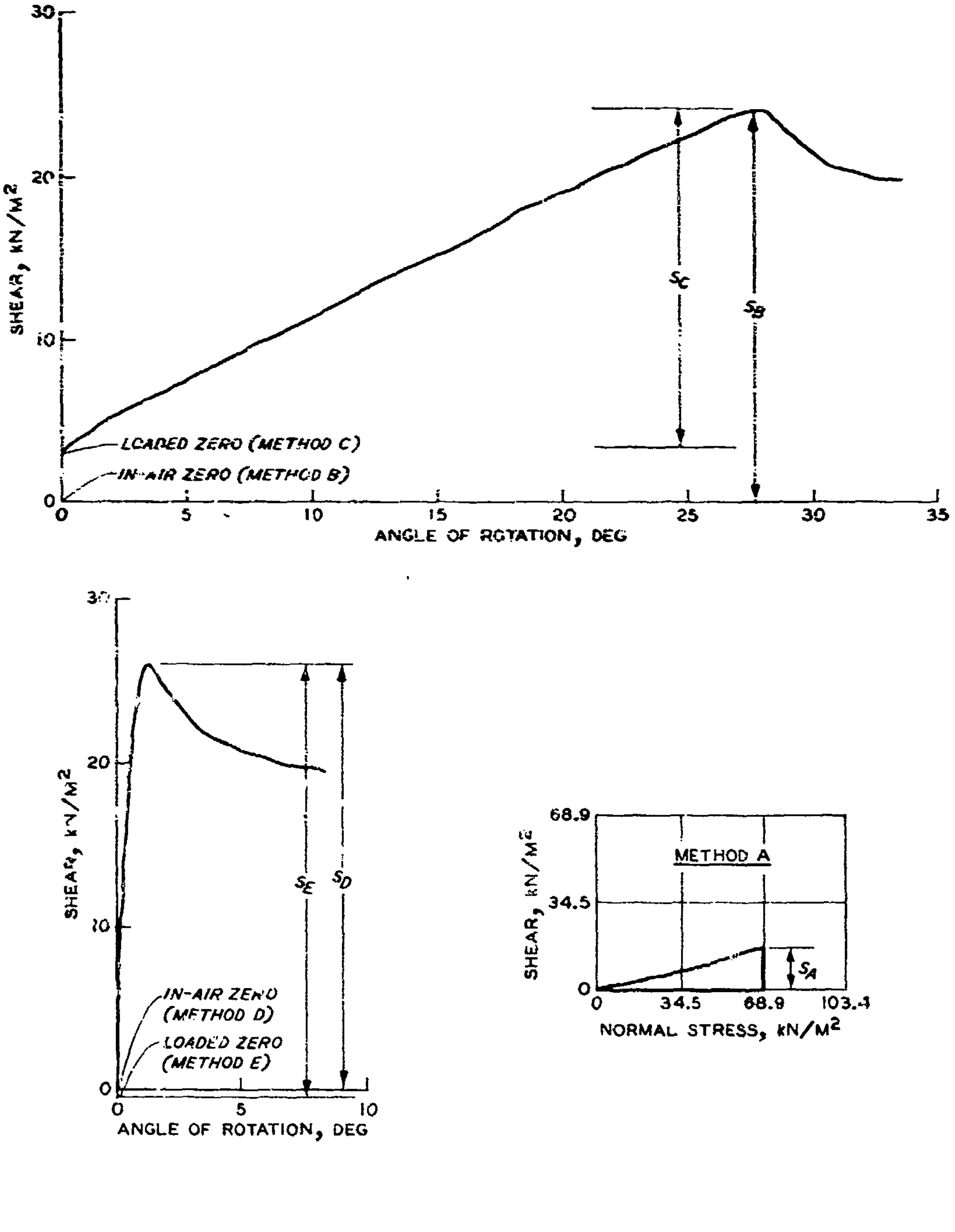

Fig. 3. Representative traces for the two instruments showing the five methods of measurements; normal pressure = 68.9 kN/m^2; surface moisture = 33.9%

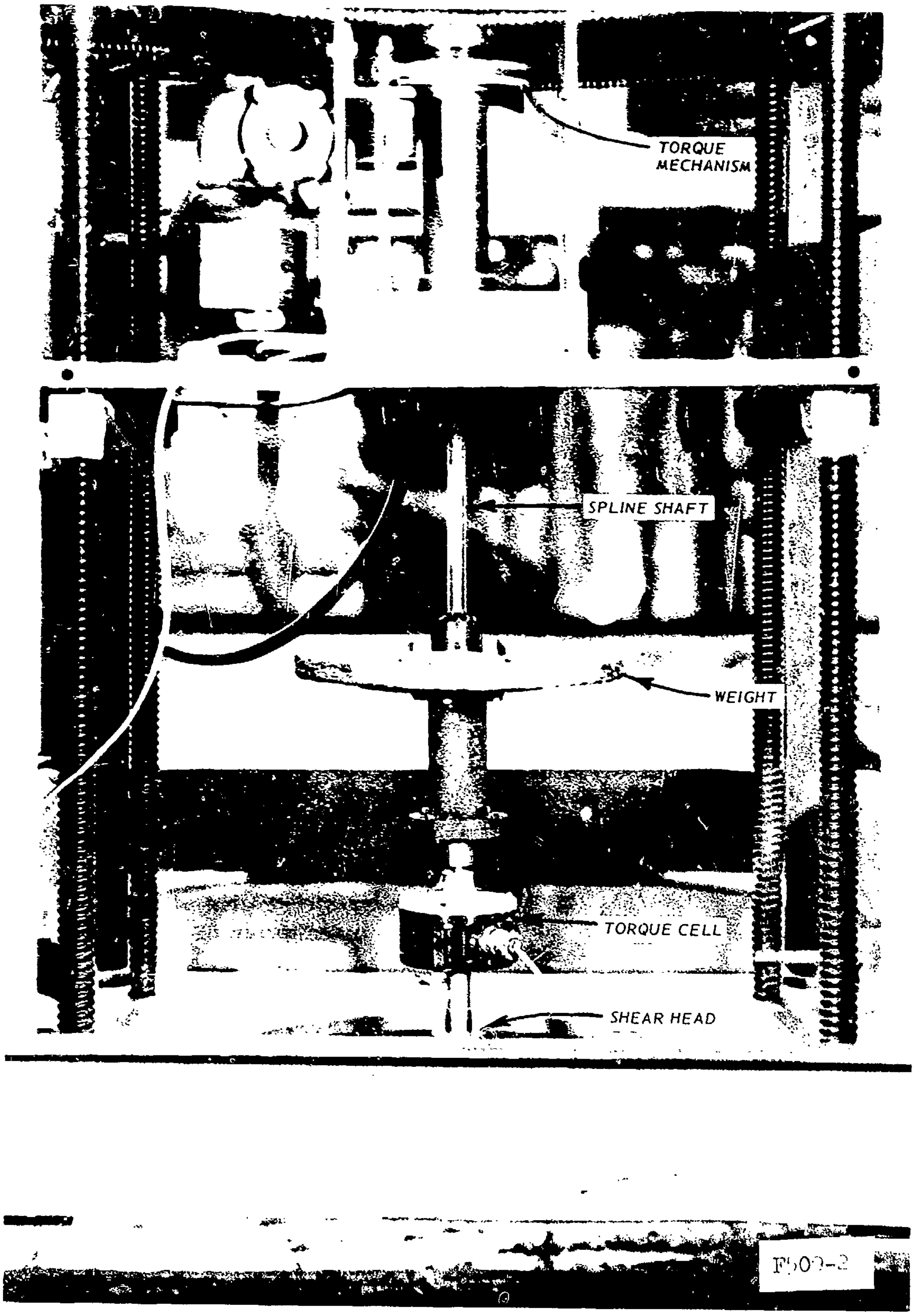

Fig. 4. Spline shear device

rotation, on an x-y recorder plot. This device does not have a barrel chart.

11 The spline shear device is first lowered far enough so that the shear head touches the soil and the shaft extends slightly into the ball bushing. Normal pressure is then applied by placing horseshoe deadweights on the ball bushing (fig. 4). In this study, the weights were gaged to produce normal pressures of 34.5, 68.9, or 103.4 kN/m^2. Finally, torque was applied as described in paragraph 8.

12. The remaining two of the five measurements studied were obtained with the spline shear instrument and are identified as having been taken by Methods D (S_D) and E (S_E), which are the same as Methods B and C (paragraph 9), except for the instrument being used. Representative results are shown in fig. 3.

Analysis of Data

13. The data obtained in this study are presented in tables 1 and 2 for tests conducted in the molds and in the soil bins, respectively. The shear values in the two tables are peak values only.

14. Shear strength of a cohesive soil generally shows a strong dependency on moisture content;[6] shear strength decreases with increasing moisture content. Because of this dependency, moisture content was used as a basis for comparing the shear data obtained from the different methods. Surface moisture content, which normally was slightly different from the bulk moisture content (see footnote on page 2), was chosen to represent the moisture content that influenced the shear strength because shearing took place directly on the surface, or approximately in the top 1-cm layer of the soil.

15. Semilog plots of log moisture content versus shear strength were developed because they produced linear relations and simplified the analysis. The standard deviations for shear strength from the regression lines (plate 1) were then calculated and used for comparing the measuring methods.

Selection of Normal Stress

16. Values of rubber-to-soil peak shear and surface moisture content for a normal pressure of 34.5 kN/m^2 are presented in plate 1. Values for normal pressures of 68.9 and 103.4 kN/m^2 are reported (tables 1 and 2), but relations were not established. Peak shear values could not be obtained for the softer soil conditions (cone penetration resistance values lower than approximately 138 and 207 kN/m^2, respectively) because of excessive sinkage of the shear head and loss of normal pressure during testing.

Selection of Method for Measuring Shear

17. The final selection of the testing method that should be used was based on general engineering judgment. The tabulation below shows that all five methods of measurement yielded reasonably good estimates of soil-to-rubber shear, but those obtained with the Cohron sheargraph (Methods A, B, and C) had smaller deviations of peak shear strength (paragraph 15) than those obtained with the spline shear instrument (Methods D and E). Therefore, Methods D and E are not recommended for use.

Normal Pressure kN/m^2	Method	Standard Deviation of Shear, kN/m^2
34.5	A	2.19
	B	1.91
	C	2.41
	D	3.32
	E	2.78

18. Although the standard deviations for Methods A, B, and C were similar, Method A is not recommended for laboratory measurements because setting the axis of the barrel chart precisely and correctly so that, in loading, the marker does not deviate from the loading axis is time-consuming and inconvenient. Also, the barrel chart is held simply by

rubber bands, which, in time, could cause problems in obtaining precise measurements of shear. However, the barrel chart must be used to determine normal pressure unless some other means such as a load cell is available.

19. Of the two remaining methods, values obtained can be recorded more simply and conveniently by Method B than by Method C because calibration of the instrument before loading, as done in Method B, is easier. Therefore, Method B, i.e. using the Cohron sheargraph with an in-air calibration, was selected as the method to be used in laboratory testing.

Conclusions

20. For controlled laboratory testing, it was concluded that:

a. The peak soil-to-rubber shear measurements should be taken at a normal pressure of 34.5 kN/m^2 to quantify the surface conditions of fat clay because, at greater pressures, excessive sinkage of the shear head occurs in soft soil in which shear measurements are of interest (paragraph 16).

b. Method B for obtaining peak shear measurements (the Cohron sheargraph calibrated in air) at 34.5-kN/m^2 normal pressure should be used in laboratory testing in saturated fat clay (paragraphs 17-19).

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Table 1

Summary of Soil-to-Rubber Shear Data; Mold Tests

Mold No.	Mold Moisture Content %	Method A Shear (S_A) kN/m²	Method A Surface Moisture Content %	Method B Shear (S_B) kN/m²	Method B Surface Moisture Content %	Method C Shear (S_C) kN/m²	Method C Surface Moisture Content %	Cone Penetration Resistance, kN/m² Surface	2.54 cm	5.08 cm	7.62 cm
					Normal Pressure = 34.5 kN/m²						
1	46.3	8.3	41.3	13.0	41.3	12.0	41.3	96.5	96.5	96.5	96.5
		8.3	43.7	10.1	43.7	9.3	43.7	117.2	110.3	117.2	110.3
2	44.2	7.6	43.3	9.7	43.3	8.9	43.3	89.6	117.2	117.2	137.9
4	44.8	9.0	41.6	13.0	41.6	11.5	41.6	110.3	110.3	117.2	117.2
		8.3	41.5	11.5	41.5	10.2	41.5	117.2	117.2	117.2	117.2
5	44.2	6.9	43.5	9.2	43.5	8.0	43.5	117.2	131.0	144.8	151.7
7	39.1	12.4	38.2	15.8	38.2	12.5	38.2	179.3	179.3	193.1	206.8
		8.3	42.0	10.3	42.0	9.2	42.0	193.1	193.1	206.8	220.6
8	39.0	8.3	38.7	12.3	38.7	11.2	38.7	186.2	193.1	193.1	206.8
12	34.4	15.9	32.7	18.2	32.7	17.6	32.7	344.7	344.7	365.4	386.1
		15.9	33.5	19.0	33.5	17.8	33.5	358.5	379.2	386.1	386.1
13	35.1	11.0	33.5	13.0	33.5	11.7	33.5	365.4	372.3	386.1	399.9
17	31.3	19.3	28.7	22.9	28.7	21.6	28.7	606.7	572.3	593.0	627.4
18	31.8	19.3	28.2	21.1	28.2	19.8	28.2	689.5	696.4	668.8	661.9
		20.0	29.1	22.3	29.1	21.1	29.1	661.9	668.8	675.7	675.7
					Normal Pressure = 68.9 kN/m²						
1	46.3	NPV*	44.1	NPV	44.1	NPV	44.1	96.5	82.7	82.7	96.5
			42.4		42.4		42.4	117.2	96.5	96.5	96.5
2	44.2		43.7		43.7		43.7	110.3	124.1	131.0	131.0
4	44.8		43.0		43.0		43.0	124.1	117.2	117.2	117.2
			42.6		42.6		42.6	124.1	131.0	124.1	117.2
5	44.2		42.8		42.8		42.8	110.3	137.9	144.8	137.9
7	39.1	13.1	40.1		40.1		40.1	179.3	193.1	199.1	193.1
8	39.0	13.8	37.5	18.4	37.5	15.6	37.5	193.1	186.2	206.8	186.2
	39.0	18.6	38.7	20.7	38.7	18.2	38.7	186.2	179.3	186.2	193.1
12	34.4	22.1	33.6	26.1	33.6	23.7	33.6	365.4	372.3	386.1	399.9
13	35.1	20.7	33.6	24.5	33.6	22.1	33.6	358.5	372.3	379.2	386.1
		20.7	33.4	24.7	33.4	22.2	33.4	365.4	372.3	386.1	399.9
17	31.3	33.1	28.4	--	--	--	--	565.4	572.3	579.1	593.0
18	31.8	37.2	27.7	41.7	27.7	38.9	27.7	737.7	717.1	696.4	675.7
19	32.2	32.4	30.1	36.0	30.1	32.8	30.1	551.6	579.2	593.0	606.7
					Normal Pressure = 103.4 kN/m²						
7	39.1	NPV	39.3	NPV	39.3	NPV	39.3	193.1	193.1	199.9	--
8	39.0		38.9		38.9		38.9	179.3	186.2	193.1	220.6
9	38.9		37.2		37.2		37.2	213.7	248.2	241.3	220.6
11	38.3		37.4		37.4		37.4	186.2	186.2	186.2	186.2
			35.9		35.9		35.9	206.8	186.2	193.1	179.3
12	34.4	22.1	31.6	28.2	31.6	23.7	31.6	358.5	379.2	386.1	386.1
13	35.1	22.1	33.7	28.1	33.7	23.6	33.7	358.5	358.5	372.3	386.1
14	33.9	24.8	32.5	30.3	32.5	26.0	32.5	358.5	386.1	379.2	372.3
17	31.3	46.9	28.1	--	--	--	--	613.6	606.7	620.5	634.3
		41.4	29.7	47.0	29.7	42.1	29.7	572.3	530.9	551.6	579.2
18	31.8	42.1	28.4	47.4	28.4	42.5	28.4	641.2	660.8	655.0	675.7

Mold No.	Mold Moisture Content %	Method D Shear (S_D) kN/m²	Method D Surface Moisture Content %	Method E Shear (S_E) kN/m²	Method E Surface Moisture Content %	Cone Penetration Resistance, kN/m² Surface	2.54 cm	5.08 cm	7.62 cm
				Normal Pressure = 34.5 kN/m²					
2	44.2	8.5	43.8	8.5	43.8	103.4	117.2	131.0	124.1
3	45.7	11.7	42.2	11.7	42.2	134.4	131.0	131.0	124.1
		9.7	44.5	9.7	44.5	124.1	117.2	124.1	117.2
5	44.2	9.3	43.3	9.7	43.3	131.0	131.0	131.0	137.9
6	43.7	9.9	43.3	9.9	43.3	117.2	127.6	131.0	124.1
		9.5	43.2	10.1	43.2	124.1	127.6	134.4	[illegible]
9	38.9	17.0	36.1	17.9	36.1	234.4	234.4	241.3	241.3
10	39.3	8.7	38.9	8.9	38.9	131.0	151.7	172.4	193.1
		11.0	41.8	11.3	41.8	124.1	124.1	151.7	199.9
14	33.9	19.7	31.6	20.1	31.6	379.2	393.0	386.1	399.9
15	34.1	21.9	33.1	22.5	33.1	372.3	379.2	399.9	420.6
		21.9	32.7	22.1	32.7	358.5	379.2	386.1	393.0
19	32.2	24.7	28.4	25.9	28.4	586.1	599.8	[illegible]	620.5
20	31.8	19.0	31.7	19.0	31.7	524.0	579.2	593.0	572.3
		20.3	31.0	20.3	31.0	549.8	599.8	572.3	565.4
21	32.0	26.3	29.2	27.9	29.2	517.1	586.0	558.5	551.6
				Normal Pressure = 68.9 kN/m²					
2	44.2	NPV	45.9	NPV	45.9	110.3	96.5	110.3	110.3
3	45.7	NPV	42.2	NPV	42.2	131.0	144.8	124.1	110.3
		NPV	43.9	NPV	43.9	96.5	96.5	117.3	124.1
5	44.2	9.5	44.7	9.7	44.7	117.2	131.0	131.0	131.0
6	43.7	8.9	43.1	8.7	43.1	124.1	131.0	137.9	137.9
		9.1	43.9	9.2	43.9	124.1	124.1	124.1	137.9
9	38.9	23.9	36.7	23.9	36.7	220.6	234.4	227.5	234.4
10	39.3	21.9	41.6	21.9	41.6	165.5	179.3	172.4	193.1
11	38.3	16.8	37.0	17.7	37.0	193.1	193.1	179.3	198.6
14	33.9	28.4	33.3	29.2	33.3	386.1	399.9	399.9	406.8
15	34.1	27.9	32.8	27.9	32.8	372.3	379.2	379.2	393.0
16	33.9	27.7	32.8	29.1	32.8	399.9	399.9	413.7	427.5
19	32.2	46.5	29.9	49.0	29.9	579.2	579.2	599.8	634.3
20	31.8	37.2	30.4	38.9	30.4	627.4	641.2	634.3	620.5
21	32.0	38.1	30.7	39.0	30.7	579.2	565.4	565.4	586.1
		40.5	30.6	41.5	30.6	544.7	544.7	537.8	579.2
				Normal Pressure = 103.4 kN/m²					
9	38.9	25.7	38.6	25.3	38.6	213.7	255.1	262.0	234.4
10	39.3	NPV	40.6	NPV	40.6	172.4	172.4	186.2	213.7
11	38.3	NPV	37.3	NPV	37.3	186.2	199.9	199.9	193.1
14	33.9	32.8	32.0	33.6	32.0	365.4	372.3	379.2	399.9
15	34.1	32.6	32.7	32.6	32.7	379.2	379.2	393.0	406.8
16	33.9	29.2	33.0	29.0	33.0	372.3	399.9	420.6	427.5
19	32.2	52.7	26.5	54.7	26.5	593.0	606.7	627.4	627.4
20	31.8	51.8	30.3	55.0	30.3	620.5	627.4	620.5	620.5
21	32.0	49.0	30.1	50.6	30.1	551.6	565.4	586.1	606.7

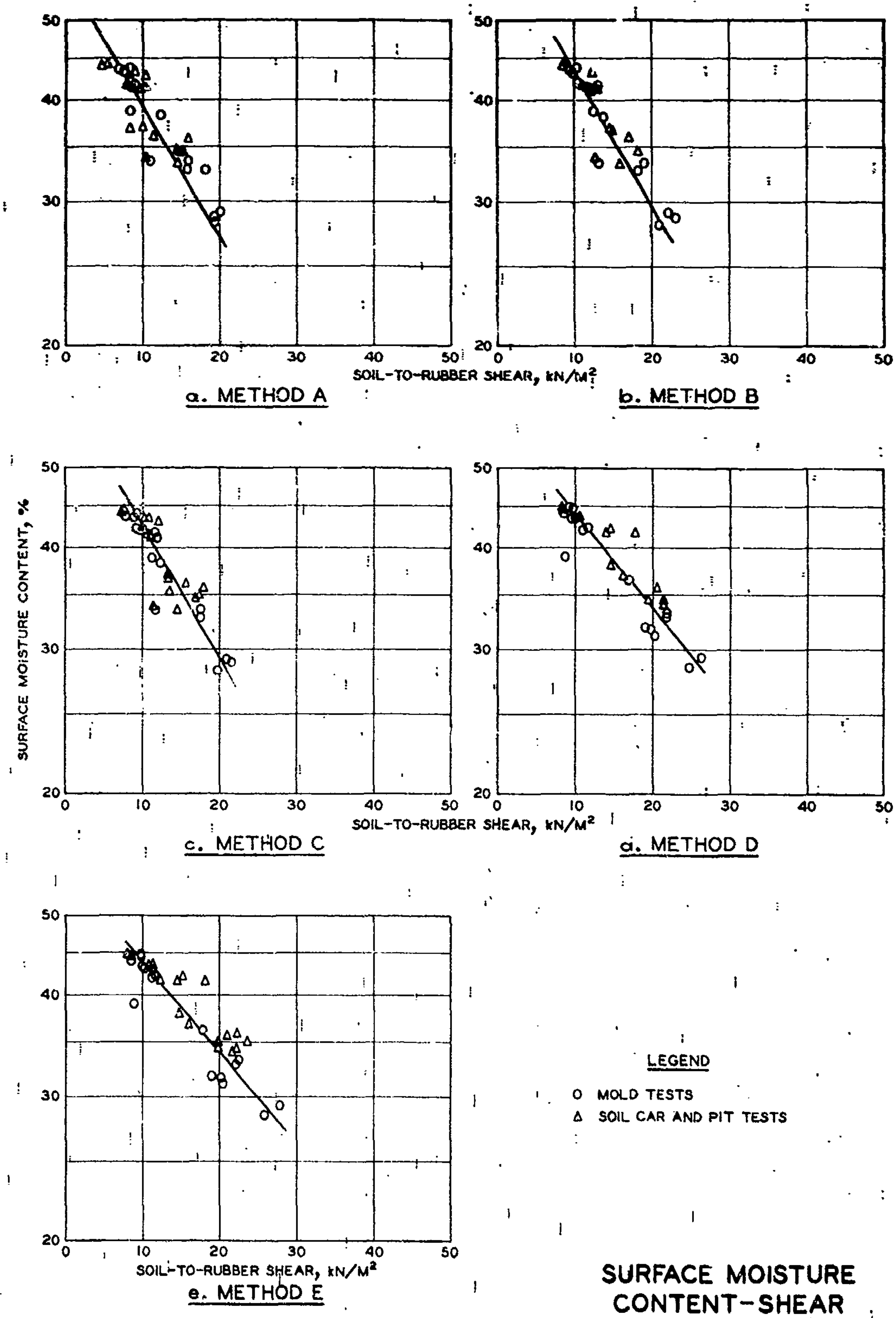
* NPV = no peak value of shear.

Table 2

Summary of Soil-to-Rubber Shear Data; Soil Car and Soil Pit Tests

Car No.	0- to 2.54-cm Moisture Content %	Method A Shear (S_A) kN/m²	Method A Surface Moisture Content %	Method B Shear (S_B) kN/m²	Method B Surface Moisture Content %	Method C Shear (S_C) kN/m²	Method C Surface Moisture Content %	Method D Shear (S_D) kN/m²	Method D Surface Moisture Content %	Method E Shear (S_E) kN/m²	Method E Surface Moisture Content %	Cone Penetration Resistance kN/m² Surface	Cone Penetration Resistance kN/m² 0- to 15.2-cm Average
Normal Pressure = 34.5 kN/m²													
1	44.3	5.5	44.3	8.4	44.3	7.7	44.3	8.1	44.6	8.1	44.6	106.9	117.2
		4.8	44.0	8.3	44.0	7.4	44.0	8.1	44.5	8.4	44.5		
		9.0	43.2	12.1	43.2	11.0	43.2	10.5	43.5	11.0	43.5		
2	40.9	9.0	41.6	--	--	10.2	41.6	--	--	12.5	41.6	197.2	224.1
		10.3	42.8	--	--	12.1	42.8	--	--	11.5	42.8		
		8.3	43.2	--	--	10.1	43.2	--	--	11.4	43.2		
		7.9	41.7	11.0	41.7	9.9	41.7	14.0	41.5	14.5	41.5		
		10.3	41.2	12.9	41.2	11.2	41.2	14.5	42.0	15.1	42.0		
		9.7	41.1	12.1	41.1	11.1	41.1	17.7	41.4	18.2	41.4		
3	35.8	15.9	35.7	--	--	18.0	35.7	--	--	23.7	34.9	349.6	390.2
		14.5	34.9	--	--	17.3	34.9	--	--	22.3	35.7		
		14.5	35.2	--	--	13.4	35.2	--	--	19.9	34.8		
		10.3	33.9	12.6	33.9	11.5	33.9	21.4	33.8	21.6	33.8		
		14.5	33.4	15.9	33.4	14.5	33.4	19.4	34.3	19.9	34.3		
		14.5	34.6	18.1	34.6	17.0	34.6	21.4	34.3	22.3	34.3		
Pit	35.7	11.4	36.0	17.0	36.0	15.7	36.0	20.3	35.6	21.0	35.6	473.7	632.9
		10.0	36.9	14.5	36.9	13.2	36.9	14.6	36.7	16.2	36.7		
		8.3	36.8	14.9	36.8	13.3	36.8	14.5	37.8	14.9	37.8		
Normal Pressure = 68.9 kN/m²													
1	44.3	NPV*	44.3	NPV	44.3	NPV	44.3	NPV	45.0	NPV	45.0	106.9	117.2
		NPV	43.5	NPV	43.5	NPV	43.5	NPV	44.2	NPV	44.2		
		NPV	43.4	NPV	43.4	NPV	43.4	NPV	42.9	NPV	42.9		
2	40.9	10.3	41.8	--	--	11.2	41.8	--	--	15.4	41.8	197.2	224.1
		10.3	42.3	--	--	11.4	42.3	--	--	14.8	42.3		
		12.4	43.5	--	--	13.0	43.5	--	--	13.1	43.5		
		10.0	40.9	14.3	40.9	11.9	40.9	15.9	41.5	16.4	41.5		
		11.7	40.3	16.8	40.3	14.0	40.3	22.4	39.0	23.1	39.0		
		12.1	41.9	15.2	41.9	12.5	41.9	17.2	41.6	17.0	41.6		
3	35.8	19.3	35.7	--	--	21.4	35.7	--	--	31.2	35.0	349.6	390.2
		18.6	35.1	--	--	21.1	35.1	--	--	27.2	[illegible]		
		17.2	25.3	--	--	18.3	35.3	--	--	27.5	[illegible]		
		17.9	33.9	21.2	33.9	18.3	33.9	26.2	34.4	26.5	[illegible]		
		19.3	34.3	21.5	34.3	18.5	34.3	28.3	34.5	29.2	[illegible]		
		18.3	34.7	21.5	34.7	18.6	34.7	28.9	34.6	29.7	[illegible]		
Pit	35.7	17.6	36.3	25.6	36.3	22.1	36.3	26.8	35.4	27.2	[illegible]	473.7	632.9
		16.2	36.7	22.4	36.7	19.2	36.7	25.9	36.3	26.3	[illegible]		
		9.0	38.3	17.0	38.3	13.8	38.3	13.8	38.5	14.5	[illegible]		
Normal Pressure = 103.4 kN/m²													
2	40.9	NPV	41.3	--	--	NPV	43.8	--	--	NPV	43.8	197.2	224.1
		↓	42.6	--	--	↓	42.6	--	--	↓	42.6		
		↓	42.7	--	--	↓	42.7	--	--	↓	42.7		
		↓	41.6	NPV	41.6	↓	41.6	NPV	41.7	↓	41.7		
		↓	41.3	NPV	41.3	↓	41.3	NPV	41.1	↓	41.1		
		↓	41.5	NPV	41.5	↓	41.5	NPV	41.0	↓	41.0		
3	35.8	20.7	35.8	--	--	21.8	35.8	--	--	32.1	35.0	349.6	390.2
		20.0	35.5	--	--	21.6	35.5	--	--	27.9	35.3		
		19.3	35.0	--	--	20.8	35.0	--	--	33.5	35.3		
		20.0	34.2	22.3	34.2	17.3	34.2	28.8	34.2	28.3	34.2		
		21.4	34.0	23.7	34.0	18.8	34.0	30.5	35.0	31.3	35.0		
		20.7	34.5	22.3	34.5	17.1	34.5	29.6	35.1	30.0	35.1		
Pit	35.7	16.2	36.2	25.4	36.2	19.5	36.2	30.3	35.9	32.8	35.9	473.7	632.9
		13.8	36.4	23.5	36.4	17.8	36.4	27.4	37.2	28.0	37.2		
		10.3	36.4	21.0	36.4	15.4	36.4	25.2	36.3	26.1	36.3		

* NPV = no peak value of shear.



SURFACE MOISTURE CONTENT–SHEAR RELATIONS

FAT CLAY; NORMAL PRESSURE 34.5 kN/M²